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Under the sponsorship of AFOSR support for two AASERT graduate PhD students from August 1993 through July 1996, there have been major advances in two fundamental areas: 1. The development of field portable Polarization Camera systems for outdoor usage. 2. The identification of practical outdoor applications through multiple data collections and analysis, particularly their promising application to Automatic Target Recognition. The report summarizes the highlights of the AASERT effort made in these respective areas:

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FINAL REPORT

AFOSR AASERT

"Methods in Physics-Based Computer Vision"
Program Managers: Dr. Dan Collins, Dr. Pat Roach
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August 1, 1993 - July 30, 1996

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Under the sponsorship of AFOSR support for two AASERT graduate PhD students from August 1993 through July 1996, there have been major advances in two fundamental areas:

- 1. The development of field portable Polarization Camera systems for outdoor usage.
- 2. The identification of practical outdoor applications through multiple data collections and analysis, particularly their promising application to Automatic Target Recognition.

This report summarizes the highlights of the AASERT effort made in these respective areas:

PORTABLE POLARIZATION CAMERAS

In 1992 a fully automated prototype polarization camera design based upon twisted nematic liquid crystal technology was developed in the laboratory and demonstrated on laboratory controlled scenes [1]. However to realize full application potential a re-design of modular and portable components was necessary in order to bring such a device outdoors, and even underwater where polarization imaging would have much potential. The AASERT effort has produced a myriad of detailed polarization images outdoors and underwater, some of which are presented in [2].

By making the design of our liquid crystal/polarizer optical head self-contained and more compact, we can now place this optical head on virtually any video camera lens. The electronics for switching the liquid crystals has also been made very compact to fit in a small box the size of the palm of a hand. These components are modular and are compatible with any NTSC camera video device. We have had success with placing these components on a small portable HI-8 video camcorder, and recording polarization component images in video format. These video images are then digitized from a high-end video frame-to-frame recorder and processed on our host workstation in the computer vision laboratory. The AASERT students have been instrumental in helping to establish the procedure for gathering, processing, and, storing polarization imagery as well as

writing the supporting software. Initial polarization images were taken of land terrain, water, and sky, revealing a multiple of physical polarization phenomena from reflection and scattering. This portable polarization camera design has been instrumental in the implementation of a doctoral dissertation in Marine Biology (just defended, December 1996) at the University of Maryland-Baltimore County for analyzing polarization vision in marine invertebrates including Octopus, Cuttlefish, Lion fish, and Mantis Shrimp. A vast assortment of underwater polarization imagery was taken literally around the world at the Australian Barrier reef, Hawaii, the coral reef off of Belize/Honduras, Venezuela, and the Red Sea. Underwater polarization light patterns were analyzed across the field of view underwater as well as off of marine animals. The principal investigator along with the AASERT students have developed physical models accounting for observed underwater polarization phenomena from reflection, transmission, and Mie and Rayleigh scattering. Similar models have been developed for segmentation of land terrain /river/ocean for Natural Object Recognition important for autonomous vehicle navigation and battlefield reconnaissance.

AUTOMATIC TARGET RECOGNITION/DETECTION (ATR/D)

One of the most important applications discovered thus far for portable polarization imagers is in providing unique capabilities for enhanced battlefield awareness in Automatic Target Detection/ Recognition systems. Orientation of polarization and partial polarization parameters of light being physically orthogonal to color and intensity are therefore immune to modified or degraded extrinsic ``appearance" of objects created by intensity and/or color camouflage, and, clutter. These polarization parameters are instead directly related to the intrinsic material composition, surface roughness, and, shape of objects [2], [3], [4]. This gives strong physical motivation for applying such a sensory modality towards the goal of detecting and recognizing man-made objects (e.g., military vehicles) that independent of extrinsic intensity and color appearance have material composition, surface properties and/or geometric properties that differ from surrounding terrain. Man-made objects having different shape characteristics and material parts (e.g., windows, viewing ports, headlight reflectors) can themselves be distinguished by various polarization signatures.

A portable liquid crystal polarization camera design was installed atop a HMMWV scout vehicle at the Lockheed-Martin, Denver Colorado facility, at the beginning of 1995. (The installation used funding from the parent DARPA grant). Approximately a half-dozen data collections were performed during the AASERT effort. A variety of polarization images were taken of HMMWVs, an M-60 tank, and an M-1 fighting vehicle. Along with the AASERT graduate students the Principal Investigator analyzed a number of polarization-based techniques to detect and recognize these man-made vehicles in environments with background clutter, including draping these vehicles with U.S. Army Woodland camouflage. We have already demonstrated capabilities of visible polarization sensing for ATR/D that are unique. For instance, to our knowledge no other sensor standardly used for ATR/D including FLIR, SAR, and LADAR can detect camouflage netting as well, at least under the conditions that we tested. At the end of the AASERT period, and currently being continued, has been the development of sophisticated polarization modeling of sky illumination and material polarization reflectance modeling for vehicle targets predicting empirically observed polarization image data [5].

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